(5) X 46260

PATENT SPECIFICATION

1,142,615

DRAWINGS ATTACHED

1,142,615

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Date of filing Complete Specification: 4 July, 1966.

Application Date: 3 July, 1965. *No. 28274/65.*

Complete Specification Published: 12 Feb., 1969.

Index at acceptance:—B5 A(1K2B, 1R58, 2Q1B, 2Q2X)

Int. Cl.:—B 30 b 11/02

COMPLETE SPECIFICATION

Improvements in or relating to production of articles from Metallic and Non-Metallic Powders

We, THE BIRMINGHAM SMALL ARMS COMPANY LIMITED, of Armoury Road, Small Heath, Birmingham 11, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to the production of articles from metallic and non-metallic powders, and is concerned more particularly with the manufacture of components by compacting a powder in a suitable die, usually followed by a sintering operation. In the case of ferrous alloys it is normally necessary to use compacting pressures in the region of 25 to 35 tons/in^2 to produce the required density, and this of necessity imposes a limit to the size of the components which can be compacted within the capacity of normal pressing equipment. As the physical properties of components manufactured from powder materials usually improve with increased density, special pressing equipment is used to produce compacting pressures up to and even exceeding 50 tons/in^2, but consequent increased tool failures render uneconomic the use of such extremely high pressures.

In order therefore to compact powder material components to relatively high densities, use is made of additional means for packing and densification of a powder mixture, in addition to the conventional punch mechanisms, whereby significantly improved physical properties are obtained.

We are aware that it is already known to use vibration for densifying brittle metallic or non-metallic powders, in which die vibration is used over a range of frequencies, and for long periods, as a means of pre-packing the powder. Such vibratory compacting is however used without or with negligible punch pressure.

According to the present invention articles are produced by the multiple impacting of powder materials by tool elements oscillated for advance and withdrawal simultaneously within a die containing a powder mass, the oscillation of one tool element being transmitted to the other tool element through the faces of the powder volume being compacted, the die also being oscillated but at an amplitude and frequency different from that of the tool elements.

The tool elements may be those of a conventional compacting apparatus, such as dies, punches or core rods.

In the method of invention, oscillation is applied as three distinct phases in the pressing cycle, firstly to assist the densification by permitting repacking of the lose powder before compression begins, secondly to assist final repacking of the powder in the initial stage of compression, and thirdly to improve the density in the final stage of compression as a consequence of the oscillatory motion of the die and lower punch relative to the compact, whereby the oscillatory action of the lower punch is transmitted from one face of the powder volume being compacted to the upper punch in contact with the other face.

As an example of the first phase of compression, iron powder fed from a filling device into a die without oscillation was weighed and compared with powder fed in the same manner with oscillation. The weight of powder in the die in the second instance was 15% more than in the first instance. The die was of circular form, $\frac{3}{4}''$ diameter, and the filling height was $2\frac{1}{2}''$. The increase in weight with oscillatory filling is equivalent to a reduction of filling height from $2\frac{1}{2}''$ to $8\frac{1}{8}''$.

The initial phase of the pressing cycle previously defined as powder densification before pressing begins, has a double advantage. By reducing the filling height required for a given length of component it enables the highly stressed punches to be shortened and thereby stiffened. It also reduces the amount of work

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done by the punches in compressing the powder to its final density.

In the second phase of the cycle, the compression of the powder between the punches begins. This phase entails further repacking of the powder as well as the onset of plastic flow as a consequence of the grains of powder being ductile. Plastic flow begins as soon as the elastic limit of each particle is reached. The completion of repacking is again assisted by the oscillation of die and punches.

In the third and final phase of compression, motion is applied in such a way that the upper and lower punches oscillate in antiphase, i.e. the upward motion of the lower punch is synchronized with the downward motion of the upper punch. This double impacting action increases in intensity as the progressive densification of the powder provides increasing resistance to the punches. The resultant reaction increases the amplitude of oscillation and consequently also the energy in the impacting action, and results in a rapid increase of density in the powder.

Simultaneously with the synchronized oscillation of the upper and lower punches, the die is also arranged to oscillate with amplitude and frequency different from that of the punches. The effect of such die oscillation is to maintain a differential movement between the die and the powder. This action substantially reduces friction between the die walls and the powder. When powder is densified by conventional methods, with steadily moving punches in a fixed die, friction between die walls and powder usually results in a considerable density variation through the height of the powder mass, with the highest density occurring near the punch faces and the lowest density in the centre of the powder, furthest from the punches. The application of suitable oscillation to the die greatly reduces this density variation, thereby improving the consistency of the powder pressing and reducing the force necessary to obtain any given density. In the subsequent sintering operation, variation of density within the powder pressing may cause variations by shrinkage or growth in the dimensions of the pressing. The improved density distribution obtainable from the use of die oscillation therefore directly affects the final tolerances of the component.

A further important advantage of the use of die oscillation is the reduction of the force required to extract the powder pressing from the die. After completion of the pressing operation the upper punch is withdrawn and the pressing is forced out of the die by the lower punch. With conventional pressing the powder usually swells horizontally, locking into any small irregularities in the surface of the die and distending the die in proportion to the vertical force applied by the punches.

Oscillatory motion of the die relative to the powder during the pressing operation prevents the powder locking into the die. In effect the movement of the die swages or burnishes the adjacent surfaces of the powder, tending to maintain a small clearance between the die and the powder pressing. The effective dimension of the pressing is therefore slightly less than with conventional pressing and the die is distended to a lesser extent. Over a series of tests with normal iron powder containing a standard pressing lubricant, it has been established that the ejection force per in^2 of the surface of the pressing in contact with the die is less than 50% of the force necessary by conventional pressing.

When the pressing is extracted from the die it expands slightly to relieve the internal compressive stresses. This expansion varies in proportion to the lateral forces induced by the pressing process and the consequent dilation of the die. Reduction of die dilation consequently gives reduction of expansion of the pressing. This reduction not only improves control of the tolerances of the final component, but also reduces the incidence of cracking in the pressing. When shaped components with sections of varying size and thickness are made, it is a common occurrance for cracks to appear in the pressing at the junction between thick and thin sections, due to progressive expansion of the pressing as it emerges from the die. Reduction of the ejection force necessary to extract any particular pressing shape directly reduces this tendency to cracking and permits the production of an increased variety of shapes.

The apparatus used in the method according to the invention is illustrated diagrammatically in the accompanying drawings in which:—

Fig. 1 shows the general arrangement of a press suitable for pressing metal powders,

Fig. 2 shows an alternative arrangement of an upper punch system having an oscillating mechanism, and

Fig. 3 illustrates an oscillating mechanism for the die.

The upper and lower rams are represented by arrows 1 and 2 which move upper and lower punches 3 and 4 respectively. The rams 1 and 2 may be moved either mechanically or hydraulically according to conventional practice, but exert only a proportion of the force necessary for compressing the powder in a die 5.

The lower punch 4 is attached to a plate 7 which has considerable mass. The plate 7 is supported upon springs one of which is shown at 8 which springs in turn are attached to the lower ram 2. A damping element 9 is provided in the spring system. An oscillating mechanism 10 is arranged to provide vertical oscillation only, and is attached to the plate 7. The lower system of the punch 4, plate 7, springs 8, damping element 9, oscillator 10 and lower ram 2, constitute a group which pro-

vides vertical motion of the lower punch 4 and permits suitable oscillation of this punch. The oscillatory force available through the lower punch is a function of the mass of the plate 7 and the punch 4, and the acceleration of the total mass provided by the oscillator 10. The amount of the oscillatory force can be calculated from the formula.

Oscillatory Force = Mass $\times$ Acceleration

The upper punch system, consisting of the upper punch 3, a plate 6, a spring system 11, a damping element 12 and the upper ram 1 is generally similar in arrangement to the lower punch system, but in this example has no oscillating mechanism. The powder filling shoe 13 moves horizontally over the face of the die 5 to cover the die aperture, and withdraws after filling is completed. The die 5 is supported in this example upon a spring system 14 and a damping element 15.

The cycle begins with the upper ram 1 raised and the lower ram 2 also fully raised to the ejection position, i.e. the upper face of the lower punch lies flush with the upper face of the die. With the oscillator 10 running, the powder filling shoe 13 is moved over the die 5 and the lower punch 4 is then moved downwards so that the die 5 fills with powder. As the filling shoe withdraws, the upper ram 1 moves the upper punch 3 downwards. When the upper punch 3 reaches the dieface the lower punch 4 is raised so that the powder within the die 5 is compressed. As the pressure of the punches 3 and 4 compresses the powder, the powder begins to transmit the oscillations from the lower punch 4 upwards to the upper punch 3. As the density of the powder further increases, the impulses transmitted through the powder increase to a point at which the inertia of the upper punch system is overcome and the upper punch begins an independent oscillatory movement which, by suitable arrangement of the relative masses of the lower and upper punch systems, can be made to synchronize in anti-phase with the lower punch oscillations, either at the same frequency as the lower punch system or at a chosen harmonic of that frequency. The increasing elasticity of the densifying powder, plus the additional energy provided by the upper punch system, cause the amplitude of both punch systems to increase, with consequent increases in acceleration and therefore in oscillatory force of both systems. The densifying action ceases when the elasticity of the pressed ductile metal powder increases sufficiently to equal the impacting force of the punches, and no more plastic flow takes place.

During the densifying cycle, the die 5 which in this example is supported upon the springs 14, is affected by the oscillatory action of the punches 3 and 4 and oscillates independently, with a frequency and amplitude which varies with the combination of its own natural frequency, the oscillatory action of the punches, and the increasing density of the powder.

Fig. 2 shows an alternative arrangement of the upper punch system in which an oscillatory mechanism 16 is attached to the plate 6. The upper punch system, as described above, must oscillate synchronously in anti-phase with the aforesaid lower punch system. A mechanical, electrical or hydraulic linkage between the lower punch oscillator 10 and the upper punch oscillator 16 is therefore essential, to maintain the necessary synchronization.

Fig. 3 shows a further alternative arrangement in which the die 5, in addition to the spring system 14 and damper 15 is fitted with an oscillating mechanism 17. This arrangement provides positive control of the oscillatory motion of the die 5 relative to the upper and lower punches 3 and 4 respectively.

The term oscillation as used in this specification may be defined as any frequency of punch or die movement between 5 and 300 cycles/sec. The amplitude of any punch or die system when not in contact with the powder may lie between $\pm.125''$ and $\pm.003''$.

WHAT WE CLAIM IS:—

1. A method of producing articles by the multiple impacting of powder materials by tool elements oscillated for advance and withdrawal simultaneously within a die containing a powder mass, the oscillation of one tool element being transmitted to the other tool element through the faces of the powder volume being compacted, the die also being oscillated but at an amplitude and frequency different from that of the tool elements.

2. Apparatus for carrying out the method as claimed in Claim 1 wherein the tool elements comprise one or more punches.

3. Apparatus according to Claims 1 and 2 comprising an upper punch and a lower punch with a die arranged therebetween, and all being oscillated simultaneously.

4. Apparatus according to Claim 3 wherein the upper punch, the lower punch and the die are each supported by resilient means.

5. Apparatus according to Claim 4 wherein the resilient means comprises one or more springs and a damping device.

6. In apparatus according to Claim 3, the inclusion of a mechanical, electrical or hydraulic linkage between the two punches to maintain synchronization between the punches and with the die when they are oscillating.

7. A method of producing articles according to claim 1 and substantially as described with reference to Figs. 1, 2 or 3 of the accompanying drawings.

8. Apparatus for producing articles as claimed in any of Claims 2 to 5 substantially as hereinbefore described with reference to Figs. 1, 2 or 3 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1969.
Published by the Patent Office, 25 Southampton Buildings, London, W.C.2, from which copies may be obtained.

This drawing is a reproduction of the Original on a reduced scale.

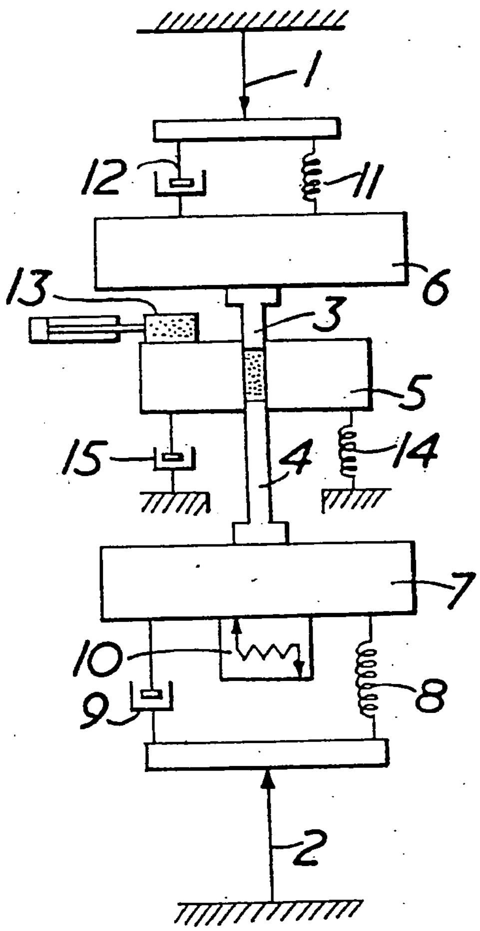

FIG.1.

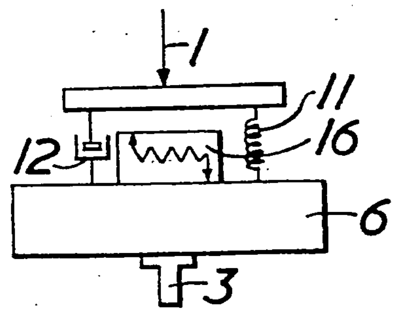

FIG.2.

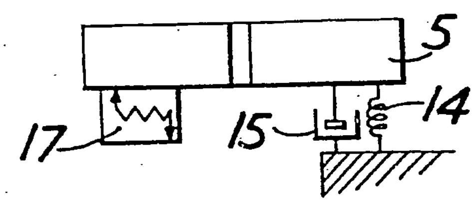

FIG.3.